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(52) UK CL (Edition R)
C1C CST C201 C417 C422 C447 C451

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INT CL[7] C02F 1/36
On-line : WPI, EPODOC, JAPIO

(54) Abstract Title
Destroying pathogens using ultrasound radiation

(57) In apparatus and method for destroying pathogens in a liquid or a mass of a liquid containing material, the liquid or liquid mass is irradiated with continuous ultrasound radiation of a frequency between 15 and 100 kHz, preferably 20 ± 1 kHz, by means of a transducer 4 in a sonication chamber 1. Preferably, the radiation power output is in the range 50-500 watts per cubic centimetre of material being treated, the amplitude of the radiation is advantageously greater than a 50 micron displacement and the method is preferably carried out at a temperature of about 15° centigrade. The transducer 4 comprises probes from which the radiation is emitted either from the whole surface area of the or each probe or preferably just from the tip. The ultrasound radiation may be combined with other forms of energy such as ultraviolet or microwave radiation, or with chemical treatment, such as with ozone.

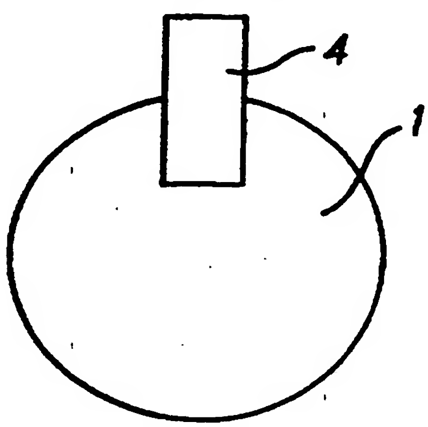

FIG. 1a

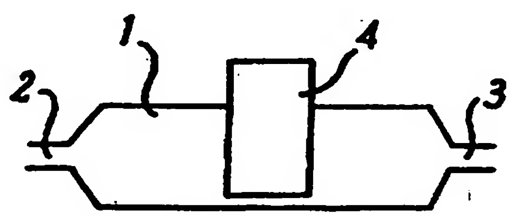

FIG. 1b

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The claims were filed later than the filing date but within the period prescribed by Rule 25(1) of the Patents Rules 1995.

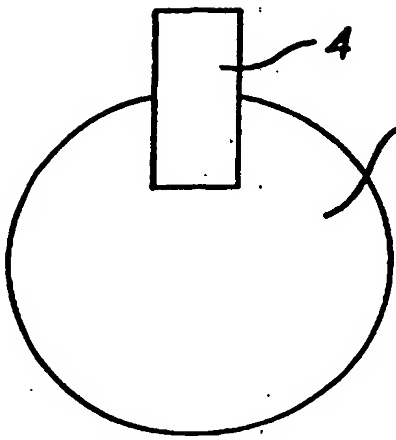

FIG. 1a

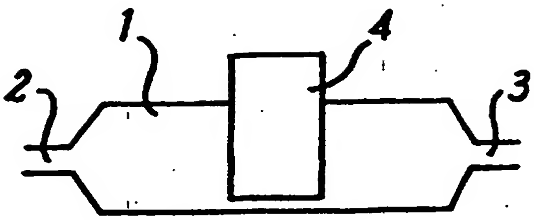

FIG. 1b

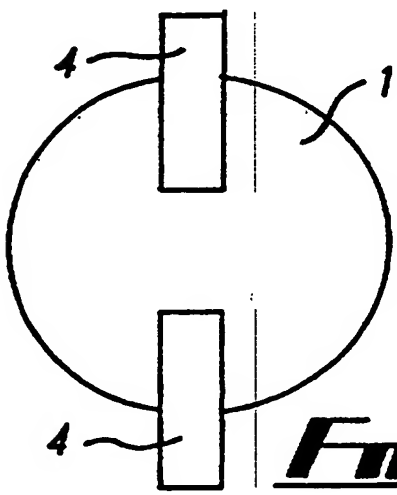

FIG. 2

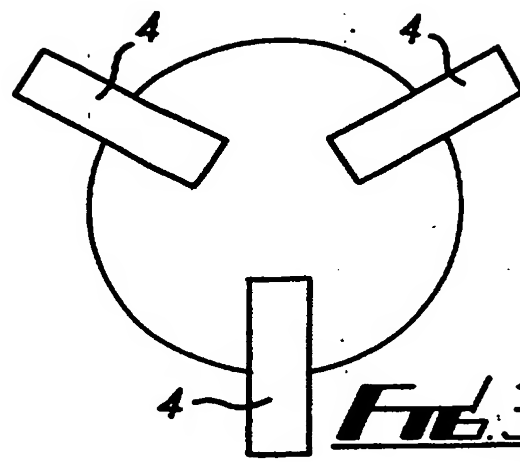

FIG. 3

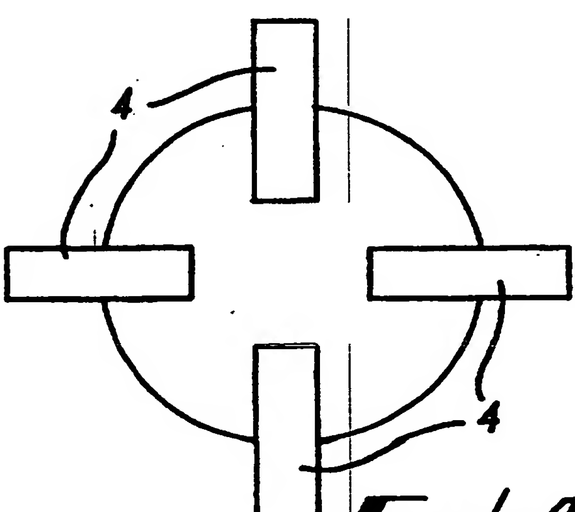

FIG. 4

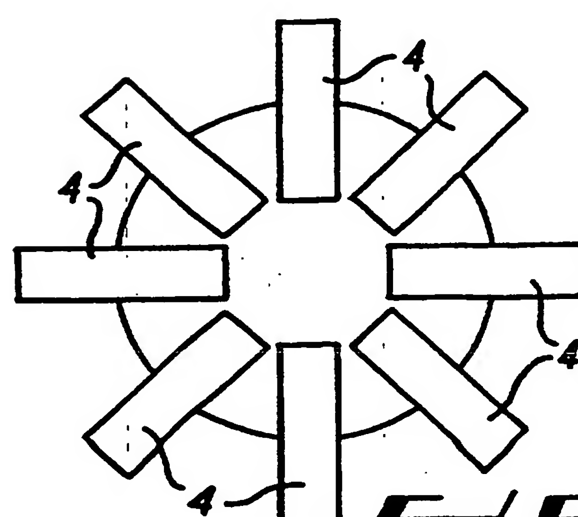

FIG. 5

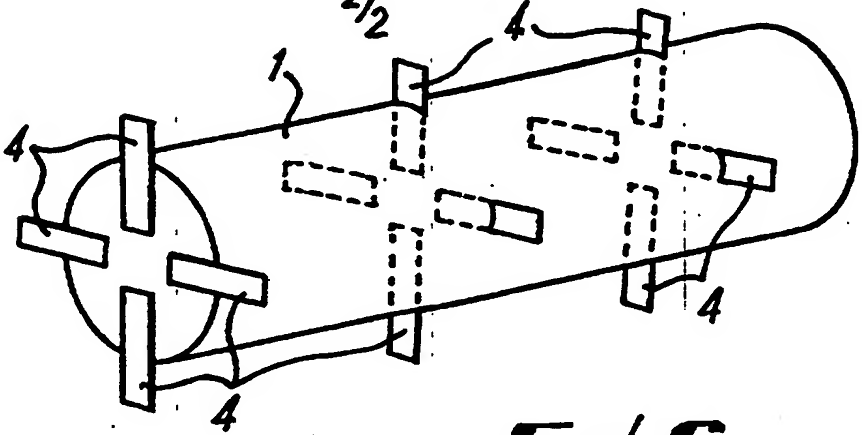

FIG. 6

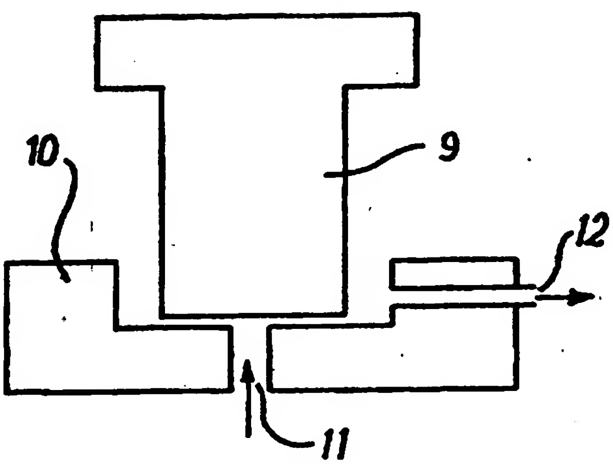

FIG. 7

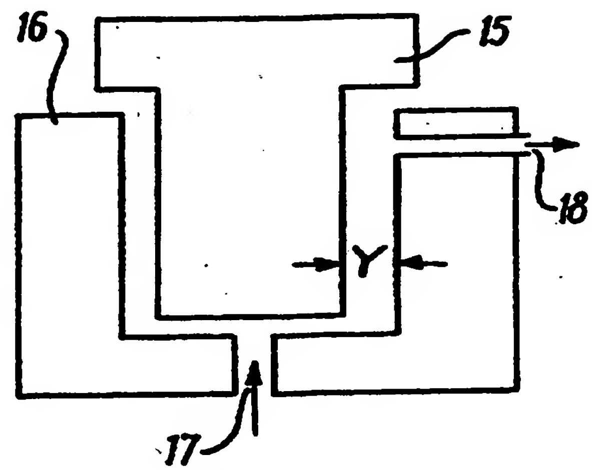

FIG. 8

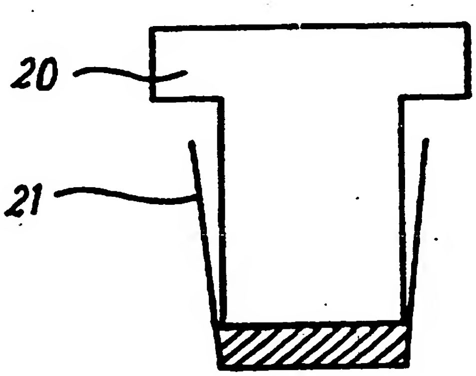

FIG. 9

APPARATUS FOR AND METHOD OF DESTROYING PATHOGENS

The present invention relates to apparatus for and method of destroying pathogens in a liquid in which the liquid or a liquid containing mass of material is irradiated with ultrasound energy.

According to one aspect of the present intention there is provided a method of destroying pathogens in a liquid or a mass of liquid containing material in which the liquid is irradiated with continuous ultrasound radiation of a frequency between 15 and 100 kHz.

According to another aspect of the present invention there is provided apparatus for destroying pathogens in a liquid comprising means for containing the liquid, and a transducer for irradiating liquid or a liquid containing mass of material in the means for containing with ultrasonic energy at a frequency within the range 15 to 100 kHz.

In a preferred embodiment of the invention, the frequency of the ultrasound radiation is 20 ± 1 kHz. Advantageously, the power output of the radiation is grater than or equal to 0.1 Watts per cubic centimetre and preferably in the range 50-500 watts per cubic centimetre of material being treated. Preferably, the amplitude of the radiation is greater than or equal to a 10 micron displacement and advantageously greater than a 50 micron displacement. The method may be carried out at a temperature in the range 0-90° centigrade and preferably about 15° centigrade. The ultrasound

radiation may be emitted from the whole surface area of the or each probe or, most advantageously just from the tip of the or each probe. The type of ultrasonic emission from the or each probe may be radial wave ultrasound or most advantageously, focussed energy. The internal diameter of the sonication chamber may be less than or equal to 20 inches and most advantageously is 2 inches. The or each probe may be made from titanium, stainless steel, aluminium, hastalloy, or any other suitable material, but is advantageously made of titanium. The sonication chamber may be circular, square, rectangular, triangular, polygonal or rhomboid, or any other suitable cross-section but is preferably of circular cross-section. The ultrasound radiation may be combined with other forms of electro-magnetic energy such as ultraviolet radiation, microwave radiation laser waves. Chemicals such as ozone may be used. Filters and/or reverse osmosis membranes and/or sonication of side tank following back flushing of filters into the tank may also be used. Any combination of these energy forms, chemicals, filters, membranes and side tank sonication may also be used.

In order that the invention may be more clearly understood, embodiments thereof will now be described, by way of example, with reference to the accompanying drawings, in which:-

Figure 1a diagrammatically shows a cross-section through a sonication chamber,

Figure 1b diagrammatically shows a longitudinal section through the sonication chamber of figure 1a,

Figure 2 diagrammatically shows a cross-section through a second form of sonication chamber,

Figure 3 diagrammatically shows a cross-section through a third form of sonication chamber,

Figure 4 diagrammatically shows a cross-section through a fourth form of sonication chamber,

Figure 5 diagrammatically shows a cross-section through a fifth form of sonication chamber,

Figure 6 diagrammatically shows a perspective view of a sixth form of sonication chamber,

Figure 7 diagrammatically shows a sectional view through an alternative type of sonication chamber,

Figure 8 diagrammatically shows a sectional view through a modification of the chamber of figure 7, and

Figure 9 diagrammatically shows a further form of sonication chamber.

Referring to figures 1a and 1b, a simple sonication chamber comprises a substantially cylindrical chamber 1 having a fluid inlet 2 and a fluid outlet 3. A transducer 4 extends into the chamber. The transducer is a 1 or 2 KW transducer and operates at a frequency of 20kHz.

The chamber of Figure 2 is similar to that of Figure 1 except that two diametrically opposed transducers 4 are provided each operating at the power levels and frequency of the transducer of the embodiment of Figure 1. The chamber of Figure 3 has three equiangularly spaced transducers 4 that of Figure 4 four such transducers and that of Figure 5 eight such transducers. In these further examples, each transducer operates at the power levels and frequency of the transducer of the embodiment of Figure 1.

In the embodiment of Figure 6 twelve transducers 4 are arranged in three groups of four spaced along the axial length of the cylindrical chamber 1. The transducers of each group of four are equiangularly spaced in a manner similar to the arrangement of Figure 4. For simplicity the inlet and outlet to the chamber 1 are not shown.

The above embodiments may be employed according to the following parameters. The or each transducer is activated to supply continuous ultrasound energy to liquid flow through the chamber. The surface of the or each transducer is in contact with the medium to be sonicated. The or each transducer is not fixed or welded to or in contact with the side of the corresponding chamber. As many transducers of as high a power as possible are employed. The following tables give possible ranges and most advantageous values for a variety of parameters.

Parameter	Possible/Preferred Range	Most Advantageous Value
Frequency	15-100 kHz	20 kHz
Power Intensity	≥0.1 W/cm^3	100 W/cm^3 or higher if technology permits
Power	1 or more transducers each of 100 W or above	2 kW transducers or higher if technology permits
Arrangement of transducers	See Figure 1	See Figure 1
Amplitude	≥10 micron displacement	50 micron displacement or greater if technology permits
Temperature	0-90°C	15°C
Site of ultrasonic emission on probe surface	Whole surface area of the probe or just at the tip of the probe	The tip of the probe
Type of ultrasonic emission from probe	Radial wave ultrasound or focussed energy	Focussed energy
Internal diameter of sonication chamber	≥20 inches	2 inches
Material from which probe is made	Titanium, Stainless steel, aluminium, hastalloy	Titanium
Geometry of flow cell	Circular, square, rectangular, triangular, polygonal, rhomboid	Circular

Optional Parameters

Parameter	Possible/Preferred Range	Most Advantageous Value
Viscosity	1-10 cps (cps = centrepoise)	n/a
Flow Rate	Static up to 10,000 gallons per minute	n/a

The following give brief details of two tests carried out to purify water.

Test 1

A 5 litre sample of water spiked with 10^9 concentration of Salmonella, E.coli, Cryptosporidium, Ascaris, Poliovirus was sonicated for 20 seconds using a 1000 W, 20 kHz ultrasonic reactor.

Results

The water was analysed after sonication, and the result was found to be a log 7 reduction (100% kill) of Salmonella, E.coli, Cryptosporidium, Ascaris and Poliovirus.

Test 2

A sample of water spiked with 10^9 concentration of Salmonella, E.coli, Cryptosporidium, Poliovirus was passed once through an ultrasonic flow-through reactor, 2 KW, 20kHz, at a rate of 30 litres per minute.

Results

The water was analysed after sonication, and the result was found to be between a log 4 and a log 7 reduction of Salmonella, E.coli, Cryptosporidium, Ascaris and Poliovirus.

Figures 7, 8 and 9 show alternative arrangements employing alternative types of transducer. In the embodiment of Figure 7, a focussed energy transducer 9 extends into an open bath 10 having an inlet 11 and an outlet 12. With such an arrangement, a lower flow rate of fluid, in which pathogens are to be destroyed, is possible. The fluid flows into the bath 10 via the inlet 11 and out of the bath via the outlet 10. In the embodiment of Figure 8, a radial wave transducer 15, which emits energy from its entire surface area, is used. As can be seen, the transducer again extends into an open bath 16 and pathogen containing fluid flows into the bath via the inlet 17 and out of the bath via an outlet 17. The transducer is energised as before to destroy the pathogens in the fluid. The transducer may be used with static fluid as well as flowing water. Rate of flow may be altered by adjusting dimension Y. This may be 0.5cm, for example. Figure 9 shows an arrangement in which a transducer 20 is disposed in a beaker 21 containing static minced beef to be sonicated.

The following table gives parameter values for a series of three tests (i), (ii) and (iii) using the arrangements of Figures 7, 8 and 9 for the

ultrasonic treatment of minced beef.

Parameter	Test (i)	Test (ii)	Test (iii)
Frequency	20 kHz	20 kHz	20 kHz
Power intensity	0.3 W/cm^3	2,800 W/cm^3	4.0 W/cm^3
Power	700 W	1400 W	200 W
Pulsed/continuous ultrasonic energy	Continuous	Continuous	Continuous
Amplitude	20 microns	25 microns	20 microns
Temperature	20°C	20°C	20°C
Flow cell dimensions	50 cm diameter	0.5 cm^3 volume	70 cm diameter
Geometry of flow cell/container	Circular	Circular	Circular
Flow rate	Static	5 gallons/minute	Static
Arrangement of transducers	See Figure 3	See Figure 3	See Figure 4

The ultrasonic radiation may be with any one or more of the following

- ultraviolet
- ozone
- microwave energy
- laser energy
- chemicals
- any form of electro-magnetic energy
- filters and/or reverse osmosis membranes and/or sonication of

side tank following back-flushing of filters into the tank.

The method may be carried out at ambient temperature and pressure or at any other suitable temperature and pressure.

It will be appreciated that the above embodiment has been described by way of example only and that many variations are possible without departing from the scope of the invention.

CLAIMS

1. A method of destroying pathogens in a liquid or a mass of liquid containing material in which the liquid is irradiated with continuous ultrasound radiation of a frequency between 15 and 100 kHz.

2. A method as claimed in claim 1, in which the power output of the radiation is greater than or equal to 0.1 watts per cubic centimetre of material being treated.

3. A method as claimed in claim 1 or 2, in which the power output of the radiation is in the range 50-500 watts per cubic centimetre of material being treated.

4. A method as claimed in claim 1, 2 or 3, in which the amplitude of the radiation is equal to or greater than a 10 micron displacement.

5. A method as claimed in claim 1, 2, 3, or 4, in which the amplitude of the radiation is greater than a 50 micron displacement.

6. A method as claimed in any preceding claim, in which the temperature lies in the range 0-90° centrigrade.

7. A method as claimed in claim 6, in which the temperature is about 15°C.

8. A method as claimed in any preceding claim, in which the radiation is radial wave.

9. A method as claimed in any of claims 1 to 7, in which the radiation

is focussed energy.

10. A method as claimed in any preceding claim, in which the continuous ultrasound radiation is combined with ultraviolet radiation.

11. A method as claimed in any preceding claim, in which the continuous ultrasound radiation is combined with microwave radiation laser waves.

12. A method as claimed in any preceding claim, in which a chemical is added.

13. A method as claimed in claim 12, in which the chemical is ozone.

14. A method of destroying pathogens substantially as hereinbefore described with reference to Figures 1a and 1b, Figure 2, Figure 3, Figure 4, Figure 5, Figure 6, Figures 7 and 8 or Figure 9 of the accompanying drawings.

15. Apparatus for destroying pathogens in a liquid comprising means for containing the liquid, and a transducer for irradiating liquid or a liquid containing mass of material in the means for containing with ultrasonic energy at a frequency within the range 15 to 100 kHz.

16. Apparatus as claimed in claim 15, in which the transducer comprises one or more probes.

17. Apparatus as claimed in claim 16, in which the transducer is operative to irradiate from the whole surface area of the or one of the probes.

18. Apparatus as claimed in claim 16, in which the transducer is operative to irradiate from the tip of the or one of the probes.

19. Apparatus as claimed in claim 16, 17 or 18, in which the or each transducer probe is operative to radiate radial wave ultrasound.

20. Apparatus as claimed in claim 16, 17 or 18, in which the or each transducer probe is operative to radiate focussed energy.

21. Apparatus as claimed in any of claims 16 to 20, in which the or each probe is made from titanium, stainless steel, aluminium, hastalloy or other suitable material.

22. Apparatus as claimed in any of claims 15 to 21, in which the internal diameter of the sonication chamber is less than or equal to 20 inches.

23. Apparatus as claimed in any of claims 15 to 22, in which the internal diameter of the sonication chamber is 2 inches.

24. Apparatus as claimed in any of claims 15 to 23, in which the sonication chamber is circular, square, triangular, polygonal or rhombic cross-section.

25. Apparatus as claimed in any of claims 15 to 24, in which means are provided for producing ultraviolet radiation.

26. Apparatus as claimed in any of claims 15 to 24, in which means are provided for producing microwave radiation.

27. Apparatus as claimed in any of claims 15 to 26, in which filters are

provided.

28. Apparatus as claimed in any of claims 15 to 26, in which reverse osmosis membranes are provided.

29. Apparatus for destroying pathogens substantially as hereinbefore described with reference to Figures 1a and 1b, Figure 2, Figure 3, Figure 4, Figure 5, Figure 6, Figures 7 and 8 or Figure 9 of the accompanying drawings.

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Application No:	GB 9825349.5	**Examiner:**	Graham S. Lynch
Claims searched:	1 to 29	**Date of search:**	14 September 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): C1C (CRT, CST, CTT)

Int Cl (Ed.7): C02F 1/36

Other: On-line : WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2265615 A BIWATER. Whole document.	1, 10, 12, 13, 15, 25.
X	WO 97/07830 AEROPAG. Whole document.	1, 15, 16, 22, 24.
X	US 5198122 KOSZALKA et al. Whole document.	1, 2, 12, 13, 15, 24.
X	US 4961860 MASRI. Whole document.	1, 15, 27.
X	US 4944886 MASRI. Whole document.	1, 8, 15, 16, 19, 27.
X	US 4086057 EVERETT. Whole document.	1, 2, 3, 15.
X	WPI Abstract Accession No. 1994-039790 & JP050345192. INA SHOKUHIN. See accompanying abstract.	1, 15.
X	WPI Abstract Accession No. 1991-372701 & JP030249985 MITSUBISHI. See accompanying abstract.	1, 6, 12, 13, 15.
X	WPI Abstract Accession No. 1989-313560 & JP010231987 KAWASAKI. See accompanying abstract.	1, 15.

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

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Examiner: Graham S. Lynch
Date of search: 14 September 2000

Category	Identity of document and relevant passage	Relevant to claims
X	WPI Abstract Accession No. 1989-223591 & JP010159094. TOA NENRYO. See accompanying abstract.	1, 15.

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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